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The use of virtualization for the recreation of historical events: The case of the 1562 *Auto de Fe of Maní* (Yucatan)

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ABSTRACT
Virtual modelling is a growing discipline which has become an important tool in the context of heritage preservation. From this point of view, its usefulness is not limited only to the reconstruction of artifacts and built structures, but it also can be an essential tool for the reconstruction of historical events. Utilizing virtual modeling it is possible to create an interactive educational experience aimed at a large audience. *Praeteritas Urbes*, in collaboration with the National Institute for Anthropology and History's (INAH) Museo Regional de Palacio Cantón in Mérida, Yucatán led a multidisciplinary group of researchers in the reconstruction of an important historical event for the history of the colonial period in the Maya area: the *Auto de Fe of Maní* held on July 12, 1562. This article discusses the methodology and the workflow used to complete the project, starting from the architectural reconstruction of the former convent of St. Michael the Archangel in the Maya town of Mani, as well as the virtual recreation of the historical characters, the built space, and the recreation of the scenario of this historical event. An important part of this project involved the digitalization of the museum's collection of archaeological pieces used for the special exhibition on the *Auto de Fe of Maní* entitled, *Ídolos: Resistencias y Persistencias.*

Section: RESEARCH PAPER

Keywords: Virtualization; 3D modelling; *Auto de fe*; cultural heritage; Maya culture

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1. INTRODUCTION

The work carried out by members of the international research group *Praeteritas Urbes* is based on research that points to a new way of interacting with cultural heritage by using virtualization and 3D modelling. Our aim has at its core an educational approach which seeks to engage the viewer's reflection and emotions to create historical empathy for the actors and agents of past events. At the same time, in-depth historical, archaeological, and cultural research is involved at all stages of the creation process, keeping in mind the basic principles that can guarantee greater reliability and historical accuracy of the virtual models created.

Praeteritas Urbes is an international interdisciplinary research group made up of historians, archaeologists, architects, multimedia specialists, as well as thematic specialists such as experts on the historical clothing, utensils, equipment, and period music, all of whom are involved in our virtual historical scenarios. The basic objective of this collective, in addition to reconstructing tangible and intangible heritage using historical reconstruction and immersive visualization, is to integrate historically reconstructed scenarios in a comprehensive and holistic way, to offer meaningful and educationally stimulating user experiences.

As many procedures and new technologies exist for creating these virtualizations (including the increasingly frequent use of Artificial Intelligence), it is necessary to integrate a theoretical corpus that allows a referential framework to direct the projects, offer various interpretations based on evidence from diverse sources, and establish scientifically valid working hypotheses to allow for subsequent cycles of project review and improvement.

The first document compiled for this purpose in the field is the London Charter (https://londoncharter.org/), of 2009, which in addition to founding the basic principles behind computer-based visualisations, also aims to establish a rigor in the field of cultural heritage and provide recommendations and guidance for visualization projects.

The principles established by the London Charter were subsequently expanded in 2017 by the ICOMOS General Assembly, which established what has been defined as the Principles of Seville, i.e., International Principles of Virtual Archaeology [1]. It is under these guiding documents that our research group undertakes our visualization projects.

In recent years, several projects have emerged that utilize virtual and immersive reality technologies for historical reconstruction. One notable example is the case study of the *Forum of Augustus*, developed by researchers from CNR - ISPC in collaboration with the Capitoline Superintendency. The aim of this work was to establish a comprehensive and reproducible workflow for creating real-time VR products, encompassing field and historical source research, 3D modelling, and a visualization methodology for all reconstructed data. The project resulted in several immersive VR products, leveraging the 3D assets produced, which included virtual reality games and exploratory applications [2]. Another example, following a similar approach to the *Auto de fe of Mani* project, is the recreation of the *Roman Villa of L'albir* (L'alfàs del Pi, Spain) by researchers at Alicante University. The project aimed to produce an animated, immersive short film offering a 360° view of the villa. This was achieved through the integration of archaeological reports, photogrammetry, and comparative historical sources. In addition to the architectural reconstruction, the project involved the development of historical characters who inhabited the scene [3].

2. CULTURAL HERITAGE AND VIRTUAL REALITY

The use of new technologies, particularly virtual recreation, creates a broader interaction of the virtual models with society, whether in a general sense, at an academic level, or as is the case with the virtual scenario of the *Auto de Fe of Maní*, to connect with local communities and their members as heirs to the historical events that have been recreated. A society's understanding of heritage helps to identify with it, improves its perception, and ultimately contributes to its continuity and preservation.

The strategy adopted by our group starts from an assumption of an educational nature, however the goals of each project also consider how the emotional factor also helps in the learning process. Creating understanding with the virtual scenario's viewer can lead to historical empathy, which is, feeling emotional identification with something or someone; improving the perception of a cultural object can directly lead to empathy for it [4].

Historical recreations must be rigorous, as dictated by the principles mentioned earlier. This requires thorough research into the historical event being recreated, encompassing the social and cultural context of the moment, as well as specific aspects such as the materials used in the clothing the characters wear, and the historical implements, assets, and other objects of the scenario's environment.

Figure 1. Maní's position on the satellite map of the State of Yucatan (GIS elaboration by Maria Felicia Rega).

3. HISTORICAL RESEARCH ON THE *AUTO DE FE*

Many of the projects that have been carried out in recent years by *Prateritas Urbes* have focused on the recreation of various historical events dealing with religious persecution that had a strong impact during the colonial period in Mexico and Guatemala. These are the "*auto de fe*" ceremonies of the episcopal and monastic inquisitions, a type of inquisitorial public "act" or spectacle which served as a processional and penitential ceremony of public repentance.

In 2019-2020, the *Prateritas Urbes* research group created a historical simulation of a 1554 *auto de fe* in Guatemala to accompany a major international temporary museum exhibit entitled "*Las imagenes de los dioses Mayas del Siglo XVI*" hosted by La Ruta Maya foundation and held in the ex-Jesuit convent which houses the Cooperación Española in Antigua, Guatemala [4].

The goal of this earlier exhibit was to display examples of Maya god images, offerings and other religious objects that were similar in nature to the Maya cultural objects destroyed at this *auto de fe* in 1554. The educational and pedagogical purpose of the VR simulation and historical recreation was to model historical empathy and tolerance for other religions [4].

Our current project, underway since 2022, is the recreation of the entire event of one of the most important of the monastic inquisition's *autos de fe* in the history of Mexico: the infamous *Auto de Fe of Maní* of 1562, Figure 1. This last major monastic *auto de fe* in the Maya town of Maní occurred on July 12, 1562, and witnessed an extensive procession of penitent Maya prisoners, and the public destruction of more than 100,000 "idols" or Maya god images. In this inquisitorial style *auto de fe* held by the friars of the Franciscan order led by the local Provincial, Fray Diego de Landa, a considerable number of religious images, sacred objects, and hieroglyphic codices [books] of Maya culture were destroyed and incinerated, followed by the condemnation of a large number of Maya people accused of practicing their traditional religion [called "idolatry" by the friars].

The work focused on two main aspects: the historical and architectural research on the Franciscan convent of Maní, and the reconstruction of the ceremony of the *auto de fe*. The results culminated in a new style of combined physical and virtual museum exhibition entitled "*Ídolos: resistencias y persistencias mayas*".

The historical research focused on:

- General aspects of the *Auto de Fe*.
- The San Miguel Arcangel convent.
- The stage and other perishable elements and structures.
- Characters and assets.

The physical and virtual exhibition centered on:

- Development of 3D models of the exhibition pieces.
- Creation of a video documentary focused on the content of the *Auto de Fe*.
- An immersive version of the historical scenario with which museum viewers could interact.
- Workshops and related cultural and educational activities.

3.1. General Concepts and Significance of the *Auto de Fe* Ceremonies

The *auto de fe*, literally meaning "act of faith," developed into a gradually larger and more elaborate ritual across the centuries. The practice of holding the ceremony which came to be called the *auto de fe* served as just one of the major ceremonial elements that the Spanish Inquisition borrowed from its predecessor, which was the medieval papal Inquisition [3]. The most important and central aspects of an *auto de fe* ceremony included:

- The procession of penitents
- The procession of the Tribunal's officers
- The Oath of Faith and the Solemn Mass
- The Sermon of Faith
- The Reading of the prisoners' sentences
- Abjurations and reconciliations of sinners/penitents
- Execution of the Punishments [5]

The *auto de fe* ceremony conveyed its message and authority through distinctive iconography (emblems, banners, costumes, and crosses) that permeated the elaborate ceremony and defined its liturgy [3]. As the scholar Francisco Bethencourt commented, the *auto de fe* "provided clear visual clues and auditory stimuli to guide the public understanding of the act of faith, essentially designed to move the senses and emotions of the spectators through symbols and rituals." [6]. Using the historical, architectural, and archaeological evidence from the case of the *auto de fe* of Maní, the final virtual simulation attempted to re-create for the museum visitor the emblems, banners, costumes and other sights, sounds, and visual imagery of this historical event (Figure 2).

3.2. The San Miguel Arcangel Convent

The convent of Saint Michel Archangel, located in the community of Maní, was one of the numerous Franciscan convents built in Mexico during the viceregal period. These convents were typically erected in densely populated pre-Hispanic settlements of significance or in central areas of nearby settlements. The convent of Maní, established by the Franciscan order, remains one of the earliest convent structures built by the Franciscan evangelizers in the Yucatán Peninsula. Established in 1547, with its official foundation as a conventual *guardianía* (mission zone) in 1549, the town of Maní was selected as the site for the new convent thanks to the alliance between Don Francisco de Montejo Xiu (the local *Halach Uinic*, or leader of the Xiu province) and the Spanish conquistador the Adelantado Don Francisco de Montejo [7].

The first impermanent structure related to the convent was built to accommodate the two initial evangelizing friars, Fray Luis de Villalpando and Fray Melchor de Benavente, and using only wood, palm, and straw, they built it "without using a single nail" as recounted by Fray Bernardo de Lizana in 1633, in his chronicle of the friars' arrival in Maní in 1547 [8].

The construction of the convent continued in various stages, with the construction of the *ramada* open-air Indian chapel being of great importance, as it allowed for the evangelization of the great number of Maya people who made up the Franciscan *guardianía* of Maní. Given the significant population at the time, this *ramada* chapel became one of the largest open- air Indian chapels ever built in the Franciscan province of San José de Yucatán [9].

The visiting Franciscan friar, fray Antonio de Ciudad Real described the state of the convent of Maní as it existed in the later sixteenth century. Writing in 1588, Ciudad Real provided a chronology of the convent's construction. The friar noted that, due to the abundant labor and materials available, the convent complex was completed in just seven years, suggesting significant progress in the construction by the decade of the 1550s. Additionally, the friar described the size of the open-air *ramada* chapel in detail, with measurements equivalent to approximately 55 meters long by 22 meters wide, ("200 feet long by more than 80 feet wide") [10]. Ciudad Real also mentions the construction of the upper and lower cloisters, the temple, a mission school, and a hospital as having been completed by that time (Figure 3).

Subsequently, in the 17th century, fray Diego López de Cogolludo mentioned in his own chronicle of the Franciscan order in Yucatan that in 1630, when Father Cristóbal de Rivera was the guardian of Maní, "he began to build a very spacious church, with three naves (intended for the Indians), but due to illness he could not finish his work, as he died in 1645." [11]

The *Catálogo de Construcciones Religiosas del Estado de Yucatán (1945) published by the Secretaría de Hacienda y Crédito Público* indicated that no progress was made in the middle of the 17th century on this earlier "spacious church" except for the construction of the foundations, as the Franciscan order instead decided to expand the existing temple, a process that was not concluded until the 18th century. By that time, they added the choir with a different access through spiral staircases up to the convent's rooftops. It is possible that during the 18th century, the wing on the north side of the convent was also added, as its

Figure 2. Virtual simulation of the *Auto de Fe of Maní* (Hans B. Erickson).

Figure 3. Proposed theoretical reconstruction of the ex-convent during the time period of the *Auto de Fe* in 1562 (model by Antonio Rodriguez Alcalá, Luis Díaz de León and Hans B. Erickson).

construction characteristics suggest a period of construction later than the original. In the 19th century, as mentioned by the American diplomat and traveller John L. Stephens, the convent was in poor condition.

In the 20th century, photographic registration of the former convent began in the decade of the 1930s with the research and publication of the "Catalogue of Religious Constructions" published by the *Secretaría de Hacienda y Crédito Público* of Mexico. Additionally, there are published photographs from the 1980s in Juan Artigas' book *Capillas abiertas aisladas* de Mexico, where an arcade in the open chapel can be observed, which is still visible in the photograph from 1992 [12].

For the digital reconstruction of the convent as it existed during the decade of the 1560s, contemporaneously with the event of the *auto de fe* held there in 1562, in addition to the aforementioned sources, a photogrammetric survey was carried out through a drone to generate a model of the current convent. This model served as the basis for the architectural analysis of the layers of construction and modifications of the convent complex. Subsequent modifications became evident in the analysis, which included the addition of the lateral belfry, the restoration of the original arcade prior to the temple's expansion in the 17th century, and the inclusion of the "*capillas posas*," or corner chapels with niches, of which only one remains today. Furthermore, based on the extant archival sources and colonial accounts, in the simulation specific vegetation was added to the atrium as described by earlier friars, including orange trees as described by Fray Antonio de Ciudad Real. The entire process of the recreation of the Franciscan convent of San Miguel Arcángel of Maní as it existed in the decade of the 1560s was carried out using the Metashape software for processing the photogrammetry and editing the base model using render software, followed by exporting the model to the *Unreal Engine* to build it into the virtual scenario of the *auto de fe* of Maní. In

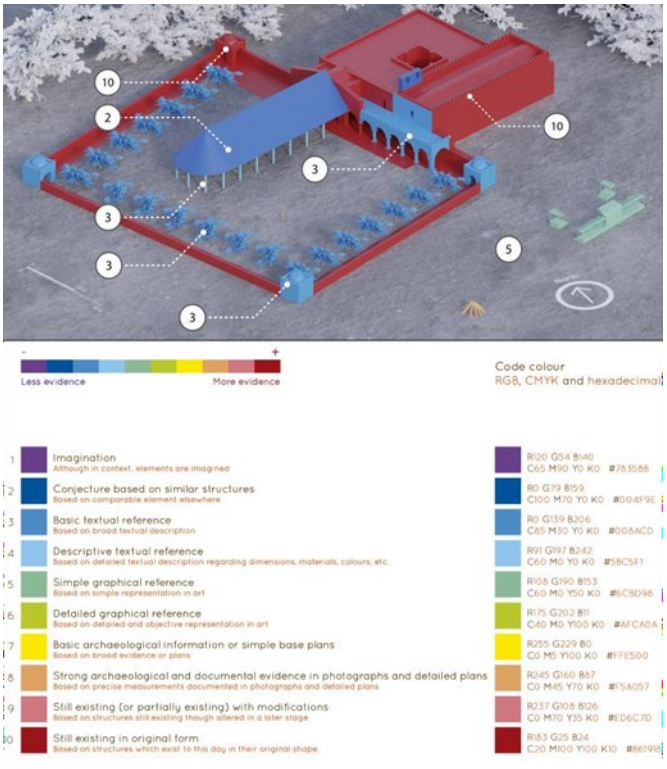

Figure 4. Proposed reconstruction according to the Historical-Archaeological Evidence Scale (process by Luis Díaz de León).

Figure 5. Proposed reconstruction of the staging of the Spanish Officials based on extant historical documentation (Recreated by Zoraida Raimúndez Ares and Hans B. Erickson).

Figure 4, the scale of the architectural and historical evidence applied for the reconstruction of the convent complex can be observed, from the currently existing elements to our hypothetical reconstructions based on the surviving evidence [13].

3.3. The Reconstruction of the *tablado* and other Perishable Structures and Elements

One of the main objectives of the historical scenario was the recreation of the staging and scaffolding which played a central role in the public spectacles of inquisitorial *autos de fe*. Luckily, for the constructions of ephemeral architecture such as the staging of the *auto de fe* of Maní, there are documentary and visual sources that can help us with the task of rescuing these temporary manifestations of public architecture and their ceremonies.

Various primary sources exist in archival collections, and other published material, that give witness to the *auto de fe* ceremony at Maní and its ephemeral architecture. These primary source documents are augmented by numerous visual and pictorial representations of similar *autos de fe*. Some of these include detailed plans, schematics and diagrams of the actual staging and platforms of ephemeral architecture built for these events [7]. The *tablado*, or the scaffolded staging of the ceremony, is one of the main perishable structures present in the *auto de fe*. Made exclusively of wood for the event, the reconstruction was based mainly on archival documents referring to the structure and comparisons with other similar structures which provided information about the general characteristics of the two sets of staging for this event (Figure 5, Figure 6 and Figure 7)

The extant archival documentation of the event offers us evidence of how the various aspects of the ephemeral architecture, and even the procession of the penitents and officials occurred. Our research team, designers, and programmers have combined efforts to as accurately as possible re-create the scene of the event. From the recreation of the Franciscan Convent of Maní as it existed in the decade of the

Figure 6. Proposed reconstruction of the staging of the Maya penitents and the effigies of the convicted idolaters based on Historical Documentation (Recreated by Zoraida Raimúndez Ares and Hans B. Erickson).

Figure 7. View of the recreation of both of the *tablados* in the Unreal Engine (models by Hans. B. Erickson and Zoraida Raimúndez Ares).

1560s (see section 3.2 above) to the recreation of the Maya town of Maní itself (see section 3.4 below), the virtual simulation included the bonfires, and the ephemeral architecture created for this event, including the staging for the Franciscan friars and the officials (Figure 5), and the wooden staging created for the display of the more than 64 effigies, or statues, of deceased Maya idolaters, and more than 200 Maya penitents processed in the *auto de fe* that day (Figure 6).

For the *Auto de Fe of Maní*, detailed descriptions have survived, such as the one by Fray Lorenzo de Bienvenida, who mentioned in one of his letters to the king, that the Provincial Fray Diego de Landa had "a large scaffold after the manner of Spain" built for the event (Figure 7) [12]. This description and many others allow for comparisons with other similar constructions of different *autos de fe* in Spain, such as the one depicted in Francisco Rizi's elaborate painting "*Auto de Fe en la Plaza Mayor (1683)*". This painting provides a general idea of how the stages for larger *auto de fe* ceremonies were constructed. Other examples of schematic diagrams of the typical types of construction for the staging of *autos de fe* in Spain also exist, such as the one from 1632 constructed in Madrid (*Proyecto de tablado para el auto de fe de 1632 en la Plaza Mayor de Madrid, 1632, Archivo General del Ayuntamiento de Madrid, Catalogo 4o, 166c, ASA, 2-390-70*).

At the same time, to create an accurate historical reconstruction, it was necessary to determine the actual location and approximate size of the staging and its placement according to the characteristics of the terrain around the San Miguel Arcángel convent. The size of the staging was estimated by considering other descriptions, such as the one given by the fiscal of the event, Bartolomé Bohórques, who mentioned in his testimony concerning the staging for the Maya penitents that they had built, "a scaffold of wood upon which they placed all those they wished to display, wearing corozas, naked from the waist up with ropes around their necks and idols in their hands" (*Testimonio del fiscal Bartolomé Bohórquez sobre los procesos de idolatría, 2 de enero 1565, Archivo General de Indias, Escribanía de Camara, 1009*) [14].

Another contemporary testimony by the Spaniard Juan de Villalobos indicated that there was another scaffold where the authorities and judges were seated: "when they arrived at the said scaffold, they climbed into the tribunal that was dedicated for the judges, the said four religious friars, and the Alcalde Mayor also was seated with them there." (*Testimonio de Juan de Villalobos sobre los procesos de idolatría, 13 de enero, 1565, Archivo General de Indias, Escribanía de Camara, 1009*) [14]. The same witness also commented that the staging for penitents was large enough to hold "a great number and quantity" of the convicted Maya idolaters.

To determine the location for the placement of the scaffolding built for this historical event, recent archaeological investigations in the area were highly useful, as the bonfire for the *auto de fe* was reportedly located in the vicinity of the convent, but without any specific location given. Combined with the terrain's topography of the vicinity around the current convent, the recent archaeological evidence of the bonfire and the remains of a great quantity of charred and broken Maya ceramic effigy censers helped with the task of the placement of the simulation. The archaeological evidence helped to determine the location of the actual site of the bonfire which gave us an accurate location to place the staging and structures for the historical recreation.

Archaeological evidence of the post holes of the exterior *ramada* chapel for the Maya, which had been made with perishable materials, combined with the archival and historical documentation also enabled an accurate reconstruction in terms of the size and dimensions of the thatched roof chapel structure in the front of the convent complex. Once again, archaeological research combined with the historical sources made it possible to determine the exact location and size of the convent's *ramada* thatched chapel as it existed during this period.

3.4. Historical Characters and Assets

An important part of the project was the creation of the historical characters who took part in the *auto de fe* as well as the cultural and historical assets that made up the various scenes of this historical event. The recreation of the historical characters and assets was also based on rigorous historical and archival research into the clothing, materials, and objects used during the mid-sixteenth century in colonial Mexico. The main software used for this process was Blender, a 3D creation suite of open-source programs that allow for the modelling and animation of digital characters along with texturing and the rendering of objects, structures, and characters. The first step in the design of more than 400 historical characters for this virtual recreation, involved the creation of the base characters using the *MakeHuman* software, an open-source application for the creation of virtual human prototypes that can be modified according to some basic physical parameters and phenotypes. In the process of creating the characters in this software it was possible to vary the physical features of the characters thanks to manual modifiers inside the software. Body measurements, such as height and weight, or other physical characteristics such as skin tone and eye colors, among others, can be changed, altered, and varied with this software. In the same way it was also possible to add hair thanks to existing templates for basic hairstyles.

The initial characters created were then exported from the *MakeHuman* program and imported directly into the Blender software, where further manual modifications were applied. Thanks to Blender's "Sculpt Mode", the character's physical features could be restructured or moulded with even more details. More specialized 3-D sculpting was needed to model some of the characteristic features of the Maya people who took part in the event. For accuracy of details, archaeological remains of Yucatec Maya burials, along with historical photographs, and ethnographic images served as sources for modelling the Maya characters for the simulation, adding comparative data with the contemporary Maya population, especially from the Yucatan peninsula and the region around the town of Maní. The modelling of the physical characteristics of the other African and

Spanish characters with their individualized phenotypes was also possible thanks to the historical and archaeological sources.

The Blender program also allowed for the addition of the details of the characters' hair or even beards and mustaches in the case of some of the male Spanish characters. One of the processes for the creation of the characters' hair involved the use of the particle system, along with the creation of hair textures and colours using another open-source software program named *FiberShop*. *FiberShop* allowed for the generation of very realistic yet low polygon models for the character's hair.

Finally, the creation of the clothing for the characters was executed directly in Blender, using planes or meshes to which physical properties are later added, including the "Cloth" modifier for fabrics. To obtain an accurate simulation, a "collision" modifier was added to the physical properties of the character, so that the plane with the properties of the fabric, "Cloth", covered the character naturally as if it were actual clothing worn by the digital character.

The clothes and other accessories, after being modelled in Blender, were then textured with the Substance 3D Painter (version 7.2) program, which allowed for creating fine and realistic textures for the clothing. The software includes alpha materials, textures, and images, but it is also possible to download or add other examples and textures from various sources (examples: https://texture.com/ or https://polyhaven.com)

Substance 3D Painter allowed exporting of textures in different formats according to the destination software. Since the final step was to import all the modelled characters into the historical simulation built in the *Unreal Engine*, we required three basic textures for our characters: the color, the normal, and the ARM, which included the ambient occlusion, the roughness, and the metallic nature of any assets present.

One of the final steps in the character creation process, before the final export into the *Unreal Engine*, was the application of an animation, which was simplified thanks to the use of the *Mixamo* program. With these animations the rigging of the characters is then carried out. The process of 3D rigging is important because it allows for the creation of 3D characters that can be animated in a realistic and detailed way. "Rigging" is the process of preparing a 3D model for animation, which involves adding virtual skeletons, called "rigs," to each of the character's mesh.

The final step was to export each element from Blender in FBX format for importation into the *Unreal Engine* simulation. Thanks to the "Blender for Unreal Engine" plugin, it was possible to transfer each character with all its physical features and the skeleton rigged for the animation directly into the Unreal program. In this way, each character was imported into the *Unreal Engine* along with its individual textures, created in Substance Painter, and applied using pre-defined master materials. Also, their animations were included according to their characteristics and roles in this historical event, following a specific order, according to the historical sources.

The scenes in *Unreal Engine* were created through the blueprints feature, where the functions and characteristics of each scenario are established, and the corresponding buildings, assets, and characters are then placed.

The characters included in the scenes were of various types: on one hand, Spanish friars, and officials, for whom we have many historical sources; and on the other hand, Maya characters of various kinds, some of whom were used as spectators or populated the house plots of the village around the main plaza. Other characters represented the main Maya protagonists of the event; most of them were penitents or convicted idolaters, each wearing a specific penitential garment "of shame" called a *sambenito* (Figure 10) that bore their name and their crimes/errors. In the said *auto de fe* "the natives were taken out naked from the waist up with *corozas* and ropes around their necks, with candles in their hands and processed around the square of the said town of *San Miguel de Maní*." [14]

For each character, where possible, information has been extracted from the various historical sources available, both written and visual, so that the physical characteristics and their penitential garments that they wore in the *auto de fe* were as similar as possible to the historical reality of the moment (Figure 9).

In several exceptional cases, the appearance of the character is known, as is the case with the Franciscan provincial Fray Diego de Landa (Figure 10). Two portraits of fray Diego de Landa are currently preserved. One of them is currently in the Convent of San Antonio de Padua, Izamal, Mexico. Another can be seen in the bishops' gallery in the meeting chamber of the Cathedral Chapter of the Cathedral of Mérida, Mexico.

Figure 8. Francisco de Montejo Xiu wearing the *sambenito* (recreation by Maria Felicia Rega).

Figure 9. Virtual recreation of the elements that made up a Mayan kitchen from the town of Maní in the 16th century (recreation by Maria Felicia Rega).

Figure 10. Diego de Landa (recreation by Zoraida Raimúndez Ares).

As for the appearance and clothing of the Spanish officials and friars, our design team utilized information from iconographic data such as sixteenth century paintings representing the colonial upper classes of that time, including sources on Franciscan friars, soldiers with their armor and weaponry from the decade of the 1560s, along with evidence about other possible characters and the typical clothing that they wore at the time.

However, the largest number of characters created for this historical event were those of the Maya, especially those who were protagonists of the procession and condemned for idolatry in the *auto de fe*. As already mentioned, for the recreation of the Maya of the 16th century, it was possible to use historical sources of the time which describe their physical characteristics, as well as their clothing. These are mainly written sources created by the Spaniards of the time [15]. These sources were enriched by ethnographic comparisons with contemporary Maya populations that retain the same phenotypes, and, in some cases, habits and customs of past centuries.

This was also essential for another aspect of the project because beyond the reconstruction of the historical event of the *auto de fe*, which took place in the main square of Maní, with the background of the former Convent of St. Michael the Archangel, our gaze also moved to the historical recreation of a hypothetical reconstruction of the village of Maní itself, where the Maya lived.

From this point of view, it became essential to also refer to archaeological sources which provided precise information on the organization of and distribution of colonial period homes and the tools and implements of daily life in Maní in the sixteenth century [7].

Daily life in Maní took place mainly in the social, family, and agricultural spheres, with agriculture being the main axis of the survival of the Maya communities. In the case of the Yucatecan Lowland Maya, archaeological, ethnohistorical, and even ethnographic evidence shows that the common Maya "household" included many different people occupying several closely aligned buildings, although in their activities they acted "as a single economic and social unit" [16].

Maya houses before the conquest followed these patterns of grouping of extended families, which could be very large. In general, there were two or three houses around a central patio. The houses were normally built with perishable materials, such as wood for the structure and palm thatching for the roof. The inhabitants of these houses often included more than one nuclear family as early colonial census records indicate (*Censo y cuenta de los indios de los pueblos de San Miguel y Santa María en la isla de Cozumel, 1570, Archivo General de Indias (AGI), Indiferente General, 1381;* also see *Cuenta y visita del pueblo de Pencuyut, 7 de septiembre, 1583, Archivo General de la Nación (AGN), Ramo de Tierras, Vol. 2809, Exp. 20*)

Despite the changes imposed by Spanish colonialism, the Mayas continued to preserve these groupings of houses made up of more than one family around these "patio groups" during the first decades after the Conquest. In general, the houses were organized into three main spaces: the living area, the external kitchen structure and various storage structures, to which other buildings could be added according to the growth of the family [17].

Some of the elements in our virtual recreation are those that formed part of the external kitchen structures. The kitchen, separated from the main building, is where the functions of food preparation and consumption were carried out (Figure 9).

Various elements and tools utilized in these Maya kitchens were designed, such as utilitarian ceramics, griddles, grinding stones and metates, as well as bags and baskets to store food, among other assets created for the simulation. These objects were primarily created using Blender and textured using the Substance 3D Painter software. The recreation of the ceramics was based on archaeological sources, mainly on technical drawings of the profiles of pottery uncovered in the excavations from Maní and its surrounding region. These profiles were imported directly inside Blender as images and then it was possible to manually draw points and lines to mark the profiles of the ceramics. After that, a modifier called "screw" automatically helps to recreate the complete 3D ceramic shape. Thanks to these archaeological sources, ceramics of different styles that were used in the 16th century in and around the town of Maní can be accurately recreated. Most of the objects created were modelled based on archaeological sources combined with ethnographic research. However, comparison with the tools still used in contemporaneous Maya communities was also important to achieve a more accurate reproduction. On the other hand, objects such as baskets, cooking fires or vegetation around the houses required a more creative approach, but always these recreations were supported by a depth of study and comparison with historical sources and ethnographic examples.

Another important aspect of the daily life of the village of Maní involved the creation of the typical agricultural practices of the time. Mainly agriculture took place in small house plots and in the more distant fields, called *milpas*, located in proximity of the town in outlying agricultural areas. Agricultural work was carried out mainly by men in the *milpas*, while Maya women dedicated themselves entirely to the cultivation of certain plants and fruits in small house plots and the preparation of food for the family members.

The *milpa* as a form of agricultural production was a typical Mesoamerican farming system that has lasted for about 5,000

years and is mainly used for growing corn (or the Mesoamerican triad: squash, corn, and beans), as well as other plants [18].

Thanks to the use of historical and archaeological sources, compared with ethnographic sources on contemporary Maya agriculture, it was possible to recreate the tools used in the work of the cornfields and in agriculture in general. Tools for planting, cutting, and harvesting plants, and other assets and elements were also incorporated to recreate more realistic scenes of daily life in the town of Maní in the sixteenth century.

The decision to also show the daily life of the Maya of Maní had the aim of bringing us closer to the more human aspects of the historical recreation as well as to the modelling of this important historical event, and to bring the current communities closer to their own history and cultural traditions.

4. HISTORICAL RESEARCH ON THE *AUTO DE FE*

Another aspect of this project was the physical and virtual museum exhibition called "Ídolos: Resistencia y persistencias mayas", dedicated to the artifacts and other elements that somehow survived the *auto de fe* and are part of the collection of the Museo Regional Palacio Cantón in Merida, Yucatán. This exhibition was co-hosted by INAH's Regional Museum of Yucatan at the Palacio Cantón, in collaboration with the historical research group, Praeteritas Urbes, Missouri State University, and the Universidad Anahuac-Mayab. The exhibit aimed to address this important historical event, 461 years after the fact, through both the exposition of more than 170 archaeological objects and virtual historical simulations in combination with the use of augmented reality and immersion rooms, as an act of historical reconciliation that offered the museum visitor with a new first-person reflection in relation to this historical event and displayed the cultural resistance and continuity of the Maya people (Figure 2).

The exhibit Ídolos, persistencias y resistencias examined the *auto de fe* celebrated in Maní, Yucatán on July 12, 1562, not only as a historical milestone but also as an educational opportunity to achieve an appreciation of the richness and complexity of Maya culture and religion. Also, on display in this exhibit for the first time were numerous archaeological pieces uncovered during the excavations of the original spot of the bonfire of the *auto de fe* of Maní conducted by Dr. Tomas Gallareta Negrón, under the generous support of Banamex. The research of the archaeological pieces and a catalogue of the exhibit was elaborated by art history, history, and museum studies students in the Honors College of Missouri State University under the direction of Dr. John F. Chuchiak IV, the curator of the exhibit, and Dr. Billie J. Follensbee, the art historical director of the student research of the pieces.

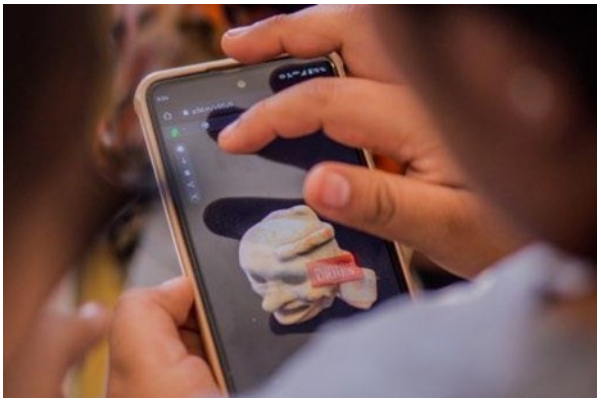

Figure 11. Museum visitor viewing one of 3D models of the archaeological pieces displayed.

4.1. Creation of 3D models and Student Research of the Cultural Objects

For the exhibition, 3D models were created for most of the archaeological pieces physically present in the exposition. Accompanied by a QR code located in the display cases, it could be scanned to visualize the piece and interact with it in its virtual version on the visitor's mobile phone (Figure 11).

The methodology of photogrammetry was employed for creating these 3D models of the exhibited pieces. The process involved systematically taking close to 200 static photographs of each piece from different perspectives. Using the Agisoft Metashape software, these photographs were compiled to virtually create a point cloud that helped to create a 3D model of the piece. By using a mesh connecting the points and a texture developed using Blender, Substance Painter, and Photoshop, the 3D models were reconstructed with high fidelity.

Initially, a special turntable tool was developed that, along with proper lighting, facilitated the image capture process. This tool allowed for the camera to be placed at different angles on a platform where the piece was positioned and rotated as seen in the following image (Figure 12).

After collecting the necessary data, the images were edited using Photoshop and then input into the Agisoft Metashape program which generated the meshes for the 3D models and their associated textures.

Once the model was created, it was exported into the Blender program, where, if necessary, the mesh is adjusted and its complexity in terms of polygons is reduced to minimize its weight, facilitating subsequent work and uploading of the model into online repositories. After post-processing the mesh, each

Figure 12. Virtual simulation of the *Auto de Fe of Maní* (Hans B. Erickson).

Figure 13. Virtual simulation of the *Auto de Fe of Maní* (Hans B. Erickson).

piece is exported to Substance Painter, where the previously edited textures in Photoshop were added, making the final 3D model ready for upload to the repository.

The archaeological pieces were categorized based on the details and research descriptions elaborated by Missouri State University Museum Studies students which will soon appear in a museum catalogue of the exhibit. The digital scans of the objects can be viewed in a virtual repository (https://p3d.in/jiJ3R) (Figure 13).

4.2. Creation of 3D models and Student Research of the Cultural Objects

The first point of contact of the exhibition, in terms of the knowledge about Maní's *auto de fe*, consisted of a documentary video whose objective was to pre-sensitize the audience about the most important historical aspects that took place in 1562, beginning with the "chance" discovery of the idols in a nearby cave, and proceeding through the investigations of the Spanish authorities, until the realization of the event of the *auto de fe*, ending with a vivid reading of a letter from one of the Maya punished in the event to convey the social and cultural consequences for the local Maya.

To carry out the elaboration of this video documentary, a large part of the content of the research was adapted in audiovisual format with the participation of both the researchers assigned to the project and Yucatec Maya-speaking scholarship recipients, who participated in the project by dramatically reading some of the original documents in the Maya language of the convicted Maya penitents, possibly some of their own ancestors sentenced more than 460 years ago. A small room was adapted to observe this looped video documentary projection, which the museum visitors entered prior to the other parts of the exhibition (Figure 14).

The video on the *Auto de Fe* of Maní (1562) can be viewed on the YouTube platform at the following link: https://youtu.be/5ghaMoFNPYI.

5. WORKSHOPS AND OTHER COMMUNITY OUTREACH ACTIVITIES

To gain an insight into the history of the former convent and its significance from the Maya community's viewpoint, some ethnographic techniques were also applied, such as ethnographic interviews and oral history interviews conducted with key actors in the community of Maní. Multiple interviews were conducted with Bertha, the secretary of the Maní parish, who has been working in the convent of Maní for years, as well as with Juan de la Cruz, whose life story, as a fundamental figure, included serving as municipal president of the town of Maní in the 1980s.

In addition to these techniques, a participatory multi-sector workshop was conducted to disseminate the research conducted thus far and share the results with the community of Maní. This workshop invited interested actors from the local community, as well as authorities from all three levels of government (including municipal, state, and federal officials). The participation included the municipal tourism secretary, along with important members of community such as local entrepreneurs, neighbours interested in the topic, and even the local parish priest. During a tour of the convent, knowledge from different local actors was shared, which was useful for the historical reconstruction of the former convent, especially the information on its recent history (Figure 15).

Furthermore, the ongoing research was shared with the local community to gather their opinions on the progress made up to that point. By socializing and presenting the research conducted

Figure 14. Museum Display of the Video Documentary in the exhibit *Idolos: Resistencias y persistencias*.

Figure 15. Tour led by Luis Díaz de León (photo by Andy Interian)

and involving the residents of Maní as participants, the entire community became engaged in the research process.

Another outreach activity carried out for the public within the museum involved crafting special clay modelling moulds made from digitized negatives created using photogrammetry. Using the resulting 3D printed moulds as precise replicas of the original Maya ceramic moulds for the making of Maya god images, in the Childrens' workshop the young participants filled them in with clay to make models of Maya god images for decoration. This exhibit proved fascinating, as the positive prints of these pieces made from the Maya ceramic moulds likely hadn't been seen in hundreds of years. Considering the delicacy of the originals, these 3D printed copies of the moulds allowed the children to create and handle the replica pieces they generated without having to use the fragile original moulds.

Among the other cultural outreach activities of the project in conjunction with the Palacio Cantón Museum of Mérida, other interactive experiences were included with children in the town of Maní, in a cultural centre called *U'luumil Cuxtal*, where attendees were able to experiment with the Augmented Reality models, as well as with the interactive model of the *Auto de Fe of Maní* (1562).

Through interviews with the individual attendees, the children said that they were aware about the existence of the *auto de fe*, but they did not know about the event or how it was executed, the approximate amount of cultural heritage that was lost, or its later cultural and social implications.

6. DISCUSSON

The state of the art in semantic or interpretive virtual models requires that all virtual simulations should allow for the manifestation and graphic characterization of the evidence that justifies the hypotheses for the recreation of the images presented. Various methods or codes have been tested and are frequently discussed in academic forums or in conservation charters such as the London Charter or Seville Principles.

These source codes denote the sources of information from which the virtual models derive. Due to the diversity of disciplines and documentary sources that can be used to create these models, each disciplinary branch often has their own validation methods. In general, in an interdisciplinary project such as this one aimed at the recreation of historical environments, it has proven useful to classify and prioritize the documentation of the main primary source evidence from the secondary sources of evidence. Both types of evidence must be tested to determine their degree of accuracy for their contribution to the virtual reconstruction in two ways:

- First, by critically confronting the evidence with digital technology. This includes, for instance, comparing historical images and cartography with surviving monumental evidence, which can demonstrate the accuracy and the presence/absence of historical components.
- Second, by recording the origin of each source of information used to create the final images, as a parallel way of offering the user an approach to the phenomenon by examining the specific knowledge used in the creation cycle, allowing for "buildable" models with the possibility of evolving and being cross-referenced with new evidence or sources.

In the creation of these virtual historical simulations, the methodological tools, therefore, must always be constantly updated, since they have the necessity of integrating a myriad of documentary sources of very diverse origins, along with a series of coherent hypotheses, into a single "buffer": the virtual models of reference.

A significant paradigm shift in the use of these new methodologies is that of the social validation of the results of the research and the models created. This refers to the acceptance and recognition by the scientific community and especially the general public of the methods, processes and conclusions used in the reconstruction and representation of similar historical events. This broad and inclusive validation of the viewers and scholarly community contributes to the credibility and relevance of all aspects addressed by the project.

In reference to the final exhibit and display of the virtualization of the *Auto de Fe of Maní* (1562), through exit surveys, guestbooks, and other data collection techniques, users of the exhibit provided valuable feedback to research teams. In the exit survey more than 60% of the visitors to the exhibit mentioned that they did not know about the *Auto de Fe of Maní*. Those who did know about it mentioned they had only heard of it in their elementary, secondary or university education.

More than 65% of users considered that the violent actions and religious persecution of the *Auto de fe* were unnecessary. One visitor to the exhibit in June 2023 exemplified many of the written comments, stating "We loved the use of technology in the exhibition. Very interesting and moving information about the Maya customs and the horror they experienced for their faith!" More than 90% considered it to be of great importance for the history of Yucatán. A total of 85% of those surveyed considered the exhibit to be of high educational and cultural usefulness. One visitor of the exhibit in May 2023 wrote in the guestbook: "Excellent exhibition with new ways of disseminating archaeological and historical knowledge. Great job from the team!"

Finally, in the qualitative comments written by users, many of them mentioned having enjoyed the reconstructions and AR applications. One visitor commented: "Excellent Exhibit! The fact that some pieces have QR codes makes it more interactive, all very illustrative and well preserved. Congratulations and thank you very much!"

7. CONCLUSIONS

Thanks to the use of deep research into the historical, architectural, and archaeological sources, it was possible to insert hundreds of characters into the virtual recreation, including more than three hundred Maya protagonists and historical actors in the event, plus more than forty Spanish officials, colonists, soldiers, and Franciscan friars. The order of the procession, along with the structures and objects of the various scenes of this historical event were inserted following a well-defined order and using the *Unreal Engine* 5.0 software for the final animations (see figures above).

The use of immersive virtual and augmented reality in this project and the subsequent museum exhibit allowed visitors to see first-hand the scale of the events and the destruction of Maya cultural heritage that occurred that day in July 1562. The reconstruction not only of the main square of Maní, but also of the houses that made up the Maya town, offered the museum visitors with a small glimpse into the daily life of the Maya in 1562.

Collaboration that involves the interdisciplinary work of an international research group implies significant challenges, not

Figure 16. Shattered remains of Maya effigy censers, or "idols", that came from the archaeological excavations of the "bonfire" pit conducted by Dr. Tomás Gallareta Negrón. (Photo by the authors)

only in the dynamics of interaction and logistics necessary to carry out cultural and historical recreation projects. But any such historical recreation project must first set a priority to decide upon the theme and narrative thread of the proposal, so that the project is coherent, respectful of the historical actors and characters portrayed, and that it has robust learning strategies for the target users. In this sense the "whole" is much more than the various "parts" of the project.

The methodological approach presented in this paper defines a typical project cycle which has not yet been closed or concluded. It is always possible to incorporate new evidence, documentation, and approaches to enrich the project, or incorporate new technological tools to improve the simulation and recreations. In essence, the primal components that make up a proposal for a historical scenario (primary historical and archival sources, along with architectural and archaeological evidence, among others), must be considered and submitted to the characteristic scrutiny of any new approaches and technologies to shed new light and evidence on the historical events under study. In effect, these projects are created to exist and adapt to constant review and data input, making them living representations of our ongoing interpretations of the cultural heritage of our past.

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